THE TRUNCATION ERROR: HOW HALF A CENTURY OF MISQUOTED RESEARCH CREATED A FLAWED STANDARD FOR RECREATIONAL PACK WEIGHT

A Critical Analysis of Ideal Body Weight Formulas, Load-Carriage Literature, and the Case for a Body-Composition-Adjusted Framework in Multi-Day Pilgrimage Trekking

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ABSTRACT

Background: The widely circulated guideline advising outdoor recreationists to limit pack weight to 10% of body weight lacks robust empirical foundation. A historical trace of this figure reveals that it represents a simplified derivative of military load-carriage research conducted on young, physically fit soldiers—a population whose musculoskeletal profile differs substantially from the middle-aged and older adults (ages 46–65+) who now constitute the demographic majority on long-distance pilgrimage trails such as the Camino de Santiago.

Objective: This paper examines the propagation of the 10% guideline through the recreational trekking community, identifies the mechanism by which clinical precision was lost during transmission (herein termed the Truncation Error), and proposes a body-composition-adjusted framework for pack weight calculation that accounts for the discrepancy between actual body weight and skeletal load-bearing capacity as estimated by ideal body weight (IBW) formulas.

Methods: A critical literature synthesis was conducted across three domains: (1) the historical provenance and mathematical properties of four major IBW equations (Devine, 1974; Robinson et al., 1983; Miller et al., 1983; Hamwi, 1964), with verification against the universal body weight equation of Peterson et al. (2016); (2) load-carriage biomechanics literature (Knapik et al., 1996; Birrell et al., 2007; Haisman, 1988; Bastien et al., 2005); and (3) NIH/NHANES anthropometric data for population-level body weight distributions. A parametric optimization was performed to identify percentage pairs that, when applied to actual body weight and inserted into

a five-value array alongside three fixed IBW/BMI-derived anchors, produce a clinically defensible gradient across the adult height-weight spectrum.

Results: The 7.7%/8.3% pairing produced the most consistent tier separation across the height range of 4'6" to 6'6" for both sexes when paired with three fixed anchors: 10% of NIH BMI-median weight, 10% of sex-specific IBW (Devine male / Robinson female), and 10% of NIH BMI-floor weight. Systematic coefficient drift was identified in secondary-source propagation of the Robinson formula, with rounded coefficients (49/1.7) producing up to 2.73 lbs divergence from original published values (48.67/1.65) at 6'6". Comparative analysis confirms that all legacy IBW equations are misaligned with BMI values at height extremes, with Devine showing 2.1–3.1% error and Robinson 0.4–0.7% error (Peterson et al., 2016).

Conclusions: The 10% guideline as currently circulated represents an oversimplification that fails to account for the discrepancy between actual weight and skeletal load capacity, particularly in overweight individuals. A five-tier array framework using body-composition-adjusted percentages provides a more physiologically appropriate range of recommendations. These findings represent a theoretical framework pending empirical validation through a planned prospective survey protocol (Phase 2) to be conducted on the Camino de Santiago.

Keywords: pack weight, ideal body weight, Camino de Santiago, load carriage, body composition, Devine formula, Robinson formula, BMI, pilgrimage trekking, Factor of Safety

INTRODUCTION

For more than three decades, recreational hikers and trekking guides have repeated a deceptively simple piece of advice: your pack should weigh no more than 10% of your body weight. This guideline has been disseminated through gear manufacturer websites, trekking forums, pilgrimage preparation guides, and word-of-mouth transmission on the trail itself. It has achieved the status of folk knowledge—widely believed, rarely questioned, and almost never cited.

This paper investigates the origins, propagation, and mathematical validity of the 10% guideline. It argues that the figure represents the end product of what the authors term the Truncation Error: a process by which qualified, context-specific findings from military load-carriage research were progressively simplified, decontextualized, and ultimately misapplied to a population (middle-aged recreational trekkers) for whom the original research was never designed.

The demographic context makes this investigation urgent. The Camino de Santiago, which attracts approximately 450,000 registered pilgrims annually, has seen a marked increase in participation among adults aged 46–65 and older—a cohort whose musculoskeletal characteristics differ meaningfully from the young military recruits who served as subjects in the foundational load-carriage studies. For this population, the gap between actual body weight and ideal body weight (IBW) as determined by clinical formulas can be substantial, and the use of actual weight as the denominator in a percentage-based guideline can produce pack weight recommendations that exceed the skeletal load-bearing capacity of the individual.

The paper is organized as follows. Section 2 traces the historical provenance of the 10% figure and documents the Truncation Error. Section 3 examines the ideal body weight formulas that serve as the clinical foundation for a corrective framework, including a forensic analysis of coefficient drift across secondary sources. Section 4 presents the mathematical modeling methodology used to derive a five-tier array of pack weight recommendations. Section 5 reports the results of the parametric optimization. Section 6 discusses implications, limitations, and the planned Phase 2 empirical validation protocol.

THE TRUNCATION ERROR: ORIGIN AND PROPAGATION OF THE 10% GUIDELINE

Military Origins

The most commonly cited primary source for load-carriage guidelines is Knapik et al. (1996), which reviewed the biomechanical and physiological effects of loaded marching in military populations. This review, published in Military Medicine, synthesized findings from studies conducted primarily on male soldiers aged 18–30 and established that increasing load magnitude was associated with increased metabolic cost, altered gait mechanics, and elevated injury risk.

Critically, Knapik et al. (1996) did not recommend a specific percentage of body weight as a universal safe threshold. The studies reviewed examined loads ranging from approximately 20%

to 60% of body weight—loads far exceeding any recreational application. The research was designed to establish operational limits for combat load, not to derive safety guidelines for multi-day walking with a daypack. Subsequent work by Knapik et al. (2004) extended this analysis to historical and medical dimensions of soldier load carriage, again within a military operational context.

The Transmission Mechanism

The 10% figure appears to have entered the recreational trekking lexicon through a process of progressive simplification. Military researchers identified that biomechanical disruption increased nonlinearly with load—a finding documented by Birrell et al. (2007), who demonstrated alterations in ground reaction forces under load, and confirmed in the more recent work of Matur et al. (2025), who quantified reductions in spinal range of motion and asymmetric muscle adaptation at 12% body weight. Outdoor recreation writers, seeking a simple guideline, extracted the lowest tested thresholds from these studies and rounded to a memorable number.

The critical context—that these thresholds were identified in fit young soldiers, that the studies used actual body weight without adjusting for body composition, and that the loads tested were substantially higher than recreational norms—was systematically removed during transmission. This process mirrors what the clinical pharmacology literature has documented in the propagation of ideal body weight formulas themselves. Pai and Paloucek (2000) traced the origin of the Devine (1974) formula and found that it was based not on population data but on empirical estimates. Despite this informal derivation, the formula was adopted as the clinical

standard for drug dosing and subsequently propagated through secondary sources with progressive rounding of coefficients and loss of contextual caveats.

Coefficient Drift as a Case Study

The propagation of the Robinson et al. (1983) formula provides a particularly instructive example of how precision degrades across citation generations. Robinson's original publication in the American Journal of Hospital Pharmacy reported the following coefficients for all frame sizes:

Male: IBW = 51.65 kg + 1.85 kg/inch above 60 inches

Female: IBW = 48.67 kg + 1.65 kg/inch above 60 inches

However, a systematic review of secondary sources reveals that many widely used calculators and reference materials cite rounded coefficients:

Male: IBW = 52 kg + 1.9 kg/inch above 60 inches

Female: IBW = 49 kg + 1.7 kg/inch above 60 inches

At 5'2" female, this rounding produces a 0.97 lb difference in IBW (114.55 vs. 115.52 lbs). At 6'6" female, the divergence grows to 2.73 lbs. Peterson et al. (2016), in their comparative analysis published in the American Journal of Clinical Nutrition, also cited the rounded Robinson coefficients rather than the original values—demonstrating that even peer-reviewed publications can propagate rounded coefficients.

This coefficient drift is not merely academic. In a system where pack weight recommendations depend on IBW calculations, and where tier separations in the proposed framework can be as narrow as 0.10 lbs, the choice of coefficients affects every downstream value. The present paper adopts the original published Robinson coefficients (48.67/1.65) for all female IBW calculations, and documents the maximum divergence from rounded versions across the height spectrum.

CRITICAL ANALYSIS OF IDEAL BODY WEIGHT FORMULAS

The Four Major Formulas

Four IBW equations have dominated clinical practice since the 1960s. All share a common structure: a base weight at 5 feet (60 inches) of height, with a linear increment per inch above that baseline. They differ in their coefficients, their empirical basis, and their alignment with modern BMI-based weight classifications.

Table 1

Four Major IBW Equations. H = height in inches. All outputs in kilograms.

Formula	Year	Male (kg)	Female (kg)
Devine	1974	50 + 2.3 × (H−60)	45.5 + 2.3 × (H−60)
Robinson	1983	51.65 + 1.85 × (H−60)	48.67 + 1.65 × (H−60)
Miller	1983	56.2 + 1.41 × (H−60)	53.1 + 1.36 × (H−60)
Hamwi	1964	48 + 2.7 × (H−60)	45.4 + 2.2 × (H−60)

Empirical Basis and Known Limitations

Devine's formula was derived empirically from clinical estimates, not from large-scale population data (Pai & Paloucek, 2000). Robinson et al. (1983) derived their formula through regression analysis of the Metropolitan Life Insurance Company height-weight tables, noting that Devine's equations overestimated the intercept and underestimated the slope—errors that cancel at average height but compound at extremes.

Shah et al. (2006) conducted the most comprehensive comparative analysis, plotting IBW formulas against BMI-derived weight ranges. Their central finding: Robinson's formula was the best IBW equation for men, but no formula predicted close to a BMI of 22 for women. They recommended using BMI ranges instead of IBW formulas for both sexes.

Peterson et al. (2016) developed a universal equation that reconciles IBW equations with BMI: Wt (lb) = 5 × BMI + (BMI ÷ 5) × (Ht − 60 in). This equation aligns with any target BMI with 0.5–0.7% empirical accuracy against NHANES data. Their alignment analysis confirmed Robinson's superiority (0.4% male / 0.7% female error) over Devine (2.1% male / 3.1% female error).

Formula Selection Rationale for the Present Framework

This paper selects the Devine male formula (50/2.3) and the Robinson female formula (48.67/1.65) for the IBW anchor in the five-tier array. This cross-formula pairing is justified on the following grounds.

For males, Devine's formula is retained because of its ubiquitous adoption in clinical protocols (ARDSNet ventilator settings, pharmacokinetic dosing) and its function as the NIH Predicted Body Weight standard. Using the clinical standard that downstream practitioners are most likely to encounter ensures reproducibility.

For females, Robinson's original formula is adopted based on its empirically superior alignment with BMI values (0.7% error vs. 3.1% for Devine female; Peterson et al., 2016). The original published coefficients (48.67/1.65) are used rather than the widely circulated rounded versions (49/1.7), consistent with the paper's methodological commitment to primary-source precision.

The known limitations of both formulas are acknowledged: neither accounts for body composition, muscle mass, bone density, ethnic variation in body proportions, or age-related changes. These are inherent limitations of the linear IBW approach, partially mitigated in the present framework by the inclusion of BMI-derived anchors that provide additional reference points.

METHODOLOGY: CONSTRUCTION OF THE FIVE-TIER ARRAY

Array Architecture

The proposed framework generates five pack weight values for any given individual based on three inputs: height, actual body weight, and biological sex. These five values are derived from three fixed clinical anchors and two variable percentage-of-actual-weight calculations, then sorted from largest to smallest to produce a tiered gradient.

The three fixed anchors are:

Anchor 1 (NIH Median): 10% of the body weight corresponding to a BMI of 21.7 at the individual's height. Calculation: Weight (lbs) = $21.7 \times (\text{Height in meters})^2 \times 2.20462$.

Anchor 2 (IBW): 10% of the sex-specific IBW at the individual's height. Male: Devine (1974); Female: Robinson et al. (1983, original coefficients).

Anchor 3 (NIH Floor): 10% of the body weight corresponding to a BMI of 18.5 at the individual's height. This represents the lower boundary of the WHO normal weight classification.

The two variable values are:

Variable 1 (Upper): 8.3% of the individual's actual body weight.

Variable 2 (Lower): 7.7% of the individual's actual body weight.

Parametric Optimization Process

The 7.7%/8.3% pairing was identified through iterative testing of candidate percentage pairs against the Devine and Robinson scales across the full adult height spectrum (4'6" to 6'6"). The optimization criteria required that the selected pair: (a) maintain proper descending sort order across the widest possible range of realistic height-weight combinations, such that the five tiers do not invert or collapse into identical values; (b) produce meaningful tier separation (minimum practical threshold of approximately 0.10 lbs between adjacent tiers) to ensure each level represents a distinguishable recommendation; (c) fall within the biomechanically supported range identified in the load-carriage literature, specifically below the nonlinear force-increase thresholds documented by Birrell et al. (2007) and Matur et al. (2025) and above the minimum necessary for essential gear carriage; and (d) demonstrate consistent internal relationships when tested against both the Devine male and Robinson female IBW anchors across the height spectrum.

The Lesser-Of Gating Rule

A critical design feature of the framework is the dynamic sort and the diagnostic information it provides. When the 8.3% actual-weight value crosses above the 10% IBW value in the sorted array, this inversion constitutes a signal that the individual's actual weight has exceeded the load-bearing assumptions embedded in the IBW formula. In such cases, the IBW-derived anchor functions as a protective ceiling, overriding the percentage-of-actual-weight calculation.

This "lesser-of" gating logic is analogous to Factor of Safety methodology in engineering, where the most conservative constraint governs the design specification. The paper acknowledges that unlike engineering Factor of Safety—which is applied to known, tested material properties—the thresholds in this framework are derived from clinical estimates with acknowledged limitations in sample size and population representativeness.

Computational Precision Standard

All source formula constants are used exactly as published in primary sources without rounding. The kg-to-lb conversion factor (2.20462) is carried to five decimal places. All intermediate calculations are maintained at four decimal places. Final display values are rounded to two decimal places using standard half-up rounding. These precision rules are documented to ensure reproducibility.

RESULTS

Sample Array Output

To illustrate the framework's output, Table 2 presents the five-tier array for a representative input: Female, 5'2", 130 lbs.

Table 2

*Five-Tier Array for Female, 5'2", 130 lbs. *Value calculated using original Robinson coefficients (48.67/1.65); rounded coefficients (49/1.7) produce 11.55 lbs.*

Tier Label	Value (lbs)	Source Calculation	Derivation	% of Actual
Max Cap	13.61	10% NIH Median (BMI 21.7)	Weight at BMI 21.7 × 10%	10.47%
Borderline	11.46*	10% Robinson IBW	48.67 + 1.65×(62−60) × 2.20462 × 10%	8.81%
Optimized	10.79	8.3% of Actual	130 × 0.083	8.30%
Ultralight	10.01	7.7% of Actual	130 × 0.077	7.70%
Expert Ultralight	9.62	10% NIH Floor (BMI 18.5)	Weight at BMI 18.5 × 10%	7.40%

Coefficient Drift Quantification

Table 3 quantifies the divergence between original and rounded Robinson female coefficients across the height spectrum.

Table 3

Robinson Female IBW Divergence: Original vs. Rounded Coefficients. All values in lbs.

Height	Original (48.67/1.65) lbs	Rounded (49/1.7) lbs	Divergence (lbs)
5'0"	107.30	108.03	0.73
5'2"	114.55	115.52	0.97
5'6"	129.27	130.73	1.46
5'10"	143.78	145.73	1.95
6'2"	158.29	160.72	2.43
6'6"	172.76	175.49	2.73

IBW Formula Alignment with BMI

Comparative alignment analysis, following the methodology of Peterson et al. (2016), confirms the differential accuracy of IBW formulas when mapped against BMI-derived weight values across the 95% height range.

Table 4

IBW Formula Alignment with BMI Values, adapted from Peterson et al. (2016). Error represents integrated percent error over the 95% height range.

Formula	Sex	Best-Fit BMI	Alignment Error
Peterson (2016)	Both	Any (user-set)	0.5%
Robinson (1983)	Male	22.5	0.4%
Robinson (1983)	Female	21.0	0.7%
Devine (1974)	Male	22.8	2.1%
Devine (1974)	Female	21.3	3.1%
Hamwi (1964)	Male	23.4	3.9%
Hamwi (1964)	Female	21.2	2.6%

DISCUSSION

The Fundamental Problem with Percentage-of-Actual-Weight Guidelines

The central argument of this paper is straightforward: when actual body weight substantially exceeds ideal body weight, any guideline expressed as a percentage of actual weight produces a recommendation calibrated to mass the skeleton did not evolve to support.

Consider two individuals of identical height (5'10" male): one weighing 170 lbs (BMI 24.4, normal weight) and one weighing 250 lbs (BMI 35.9, Class II obesity). A simple 10% guideline

prescribes 17 lbs and 25 lbs respectively. Yet both individuals share approximately the same skeletal frame—the same vertebral cross-sections, the same pelvic girdle dimensions, the same joint surface areas. The additional 80 lbs in the second individual is predominantly adipose tissue, which contributes to ground reaction forces but does not increase the structural capacity of the load-bearing skeleton.

The five-tier array addresses this by incorporating IBW-derived and BMI-derived anchors that are functions of height alone, independent of actual weight. For the 250 lb individual above, the 8.3% actual-weight value (20.75 lbs) would be sorted against the 10% Devine IBW value (approximately 17.2 lbs), and the array's sort inversion would signal that percentage-based guidance has exceeded the skeletal reference frame.

The Non-Linear Scaling Problem

Birrell et al. (2007) demonstrated alterations in ground reaction forces with increasing backpack load in military subjects, establishing the principle that biomechanical cost does not scale linearly with load magnitude. Matur et al. (2025) extended this understanding to EMG and range-of-motion parameters, finding that even at 12% body weight, backpack carriage reduced erector spinae and multifidus activation while restricting spinal range of motion and producing asymmetric compensatory adaptations. Sturdy et al. (2025) further quantified these effects at the lumbar spine level, demonstrating that walking slope and backpack load interact to increase peak and impulsive lumbar joint contact forces—findings with direct relevance to multi-day pilgrimage walking on varied terrain.

This nonlinearity interacts with the percentage-of-actual-weight problem: an overweight individual applying a percentage guideline to their actual weight compounds two separate sources of excess load—the mass of body tissue exceeding ideal weight, and the pack mass calibrated to that excess. The five-tier array framework addresses only the latter, but in doing so it removes one variable from the compounding equation.

Implications of the Kang et al. (2019) Pediatric Findings

Although this paper focuses on adult recreational trekkers, the Kang et al. (2019) comparative study of seven IBW calculation methods in 1,442 pediatric patients is methodologically instructive. Their finding that the Devine method produced the largest mean difference from the McLaren reference method in older children (mean difference 6.04 kg, $p < 0.001$) provides independent evidence that Devine's formula produces clinically significant divergence from growth-chart-based references—particularly at height extremes. This supports the present paper's decision to use Robinson's more empirically grounded formula for the female IBW anchor.

Age-Related Gait Considerations

The target demographic for this framework—adults aged 46–65 on multi-day pilgrimage routes—faces age-related changes in gait stability and musculoskeletal function that compound

the load-carriage risks identified in primarily younger military populations. Liang (2024) demonstrated that age affects the dynamic interaction between kinematics and gait stability, with older adults showing significantly different center-of-mass and base-of-support relationships during walking compared to younger adults. Siragy et al. (2024) further documented age-related differences in mediolateral margin of stability that highlight altered motor strategies for maintaining dynamic balance. These findings underscore that load-carriage thresholds established in young military populations cannot be extrapolated without adjustment to older recreational trekkers.

The Peterson Universal Equation as Validation Framework

Peterson et al.'s (2016) universal equation—Wt (lb) = 5 × BMI + (BMI ÷ 5) × (Ht − 60 in)—provides an independent mathematical framework for validating the NIH-derived anchors in the five-tier array. Because this equation can calculate body weight at any target BMI with 0.5–0.7% empirical accuracy, it offers a verification path for the BMI 18.5 and BMI 21.7 anchor calculations that does not depend on the IBW formulas themselves. Future iterations of the framework may incorporate this equation directly to replace the IBW anchor with a BMI-aligned alternative, addressing Shah et al.'s (2006) recommendation to move away from linear IBW formulas entirely.

Field Evidence from Backpack Hiking Research

Stoltzfus et al. (2022) conducted a prospective cohort study of 1,206 hikers at Philmont Scout Ranch and found that obesity and prior injury history were associated with musculoskeletal injury risk during 12-day backpacking treks. Although this study did not test the specific 7.7–8.3% threshold, its findings that pack weight management policies and counseling of obese individuals may mitigate injury occurrence are consistent with the body-composition-adjusted approach proposed here. The Stoltzfus et al. (2022) findings represent the most relevant prospective field data currently available for recreational backpack hiking, and the planned Phase 2 survey on the Camino de Santiago is designed to extend this evidence base to the adult pilgrimage population.

LIMITATIONS

This study has several important limitations that constrain the strength of its conclusions.

First, this paper represents a literature synthesis and mathematical modeling exercise, not an empirical study. The 7.7%/8.3% pairing is the output of parametric optimization within a modeled environment; it has not been validated against field data from actual trekkers.

Second, the foundational load-carriage studies (Knapik et al., 1996; Birrell et al., 2007; Haisman, 1988) were conducted primarily on young military-age male subjects. Extrapolation of

their findings to middle-aged and older recreational trekkers of both sexes introduces population-validity uncertainty that cannot be quantified without age-stratified load-carriage research.

Third, the IBW formulas used as anchor calculations were derived from predominantly white, middle-class American and European populations from specific historical periods (1960s–1980s Metropolitan Life Insurance data). Their applicability across ethnic groups, body types, and contemporary population distributions is limited (Shah et al., 2006; Peterson et al., 2016).

Fourth, the framework does not account for terrain type, elevation profile, ambient temperature, pack design and fit characteristics, or individual fitness level—all of which affect the relationship between pack weight and biomechanical stress. The interaction of walking slope and load on lumbar joint contact forces documented by Sturdy et al. (2025) is particularly relevant for pilgrimage routes with significant elevation changes.

Fifth, the model-derived consistency scores reported in preliminary iterations of this work are internal measures of how well candidate percentage pairs maintain sort-order integrity across the height-weight spectrum. They should not be interpreted as clinical reliability statistics or compared to reliability coefficients from empirical psychometric or clinical studies.

Sixth, sample sizes in some cited studies are small (e.g., Shymon et al., 2014, N=6 for spinal ROM under load; Liang, 2024, N=30; Siragy et al., 2024), limiting the precision of threshold estimates derived from those studies.

PHASE 2: PROPOSED EMPIRICAL VALIDATION PROTOCOL

The theoretical framework presented in this paper generates a testable prediction: that when recreational trekkers on the Camino de Santiago self-optimize their pack weight through trial and field experience, the resulting final pack weights will cluster in a range corresponding to approximately 7.7–8.3% of actual body weight for the median participant.

The planned survey protocol will collect the following data points from consenting adult participants at multiple points along the Camino Frances route:

(a) Demographic data: age, biological sex, height, pre-departure actual body weight (self-reported, with measurement protocol guidance).

(b) Initial pack weight: total loaded pack weight at departure, measured by digital luggage scale.

(c) Items removed or shipped: weight and description of items removed from pack during transit, with timing of removal.

(d) Final self-optimized pack weight: total loaded pack weight at the point where the participant reports that the pack felt right for sustained daily walking, measured by digital luggage scale.

(e) Optional: musculoskeletal symptom self-report (joints, back, feet) at departure and at self-optimization point.

The primary analysis will compute the ratio of final self-optimized pack weight to actual body weight for each participant and examine the distribution of these ratios across the sample. The hypothesis is that the median ratio will fall between 0.077 and 0.083 (7.7–8.3%). Secondary analyses will examine whether the distribution varies by age cohort, sex, BMI category, or prior trekking experience.

This protocol has been designed for field deployment during the 2026–2027 trekking seasons. IRB exemption or approval status, informed consent procedures, and data management protocols will be documented in a separate Phase 2 protocol paper.

CONCLUSION

The 10% pack weight guideline, as currently circulated in the recreational trekking community, is the product of a multi-decade Truncation Error in which qualified military research findings were progressively simplified, decontextualized, and applied to a population for which they were never intended. The parallel history of ideal body weight formulas—where empirical estimates were adopted as clinical standards, coefficients were rounded through secondary-source transmission, and formulas were applied outside their original pharmacokinetic context—demonstrates that this kind of precision degradation is not unique to the trekking domain.

This paper proposes that the question of optimal pack weight cannot be answered with a single number. Instead, a five-tier array that incorporates clinical anchors (IBW, BMI-derived weight ranges) alongside percentage-of-actual-weight calculations provides a graduated set of recommendations that adapts to the individual's body composition. The key insight is not the specific values of 7.7% and 8.3%, which await empirical validation, but rather the structural observation that percentage-of-actual-weight guidelines systematically fail when actual weight exceeds ideal weight—and that this failure is diagnostically visible when a framework includes both percentage-based and composition-based reference points.

The planned Phase 2 empirical study will test whether the 7.7%/8.3% range corresponds to the self-optimized pack weights that experienced trekkers converge on through field experience. Whether the hypothesis is confirmed, modified, or refuted, the resulting data will provide the first dedicated empirical dataset for recreational pilgrimage pack weight optimization—a contribution to a field that has operated on anecdote for far too long.

CONFLICT OF INTEREST STATEMENT

The author is the founder of Project 21F LLC and the European Trekking Standard & Protocol Registry (ETSPR). The mathematical framework described in this paper is implemented in a publicly available calculator application developed by the author's organization. No external funding was received for this research. All source data, formulas, and computational methods are documented transparently to support independent replication and verification.

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